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Designing PIGSAFE: Pig Industry Geographic Surveillance and Assessment for Fever Emergencies Against African Swine Fever

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Abstract: Outbreaks of the African Swine Fever disease pose serious risks to economic stability, food security, and public health. It has affected countries around the world, including the Philippines. The Philippines has no centralized and real-time application that serves as a data-driven tool that communicates the magnitude of the problem and helps guide public animal health awareness and responses. One of the problems is understanding the risk factors related to ASF and how its presence causes the spread of the disease. Therefore, the management of ASF requires a web-based geographic information system that integrates the different ASF risk factors in mapping the risk and occurrence of ASF disease. This paper presents the design and development of PIGSAFE (Pig Industry Geographical Surveillance and Assessment for Fever Emergencies), a tool for ASF that harnesses the capability of risk assessment and surveillance mapping of pig farms in Echague, Isabela. It includes the ranking of different biosecurity and spatial risk factors, which is very critical in the management of ASF as it is used to get the overall risk level of each pig farm. The web application facilitates the identification of risk levels of different farms and the creation of risk and heat maps that can support decision-making processes and aid in implementing control measures. Rapid Application Development (RAD) method was used in the software development life cycle. It utilizes MapBox in creating GIS functionalities for the ASF disease real-time monitoring, enabling disease incident outbreak reporting and mapping that can aid in targeted interventions. The system's user-friendly interface allows stakeholders to easily access and interact, facilitating data sharing and collaborative decision-making. It, thus, opens the avenues toward the use of web-based GIS technology and its potential in integrating risk assessment to revolutionize animal disease surveillance, whereby proactive ASF disease risk assessment and management can take place.

Introduction

African Swine Fever ASF emerged to become one of the major issues globally, particularly affecting Asia and the Philippines' swine sector. It has pummelled the pig industry in the Philippines since 2019 and severely impaired food security and small farmers' livelihoods (Fernandez-Colorado et al., 2024). Following its introduction in 2019, ASF led to high mortality rates among pigs and substantial economic losses amounting to 200 billion pesos (*Hog Industry Losses Due to ASF Hit P200 Billion* | Philstar.Com, 2023), prompting government intervention through enhanced surveillance, strict biosecurity measures, and culling infected animals. The ASF has already affected 458 barangays in 74 provinces as of August 2024, including putting heavy impacts on the local pig farms (ASF Situation in Asia and Pacific Update, 2024). The northern part of Luzon, especially the Cagayan Valley region, was hit heavily, and the Isabela province experienced numerous outbreaks. It caused massive deaths in pigs and enormous economic losses in such a way that it forced the government to intervene. This calls for the National

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Zoning and Movement Plan that implemented the mandatory ASF disease surveillance, aggressive testing, and prompt destruction of pigs within a 1-kilometer area. Mass culling resulted in economic loss and a hike in the prices of pork products.

The main goal of effective surveillance is early detection and control of the disease (Fernandez-Colorado et al., 2024; Kumar et al., 2021). The Philippines, however, continues with the traditional way of surveillance and reactive measures. There are limited reported cases of ASF because of the loss it would have on the pig owners' economy due to mass culling adopted by the government. This leads to probable cases of ASF not being reported or reported late due to its continuous spread. This highlights the need to report suspect cases of ASF immediately for response by animal health authorities (Hsu et al., 2023). In addition, the relevant authorities are more concerned with fast responses rather than the long-term preventive measures (Fernandez-Colorado et al., 2024) such as high-level mass culling and pig movement restrictions. Second, some have highlighted the emphasis on biosecurity and spatial risk factors in understanding the epidemiology of ASF. Previous studies have proved that the understanding of the epidemiology of ASF calls for complex interplays with risk assessment methodology (Martínez-López et al., 2015). These methodologies are of much importance and help in the isolation of such potential areas or populations of pigs, paving the way for making informed decisions by the authorities that can be followed through by the implementation of the intended interventions in specified targeted areas.

In line with this, the researcher's focus for this study is to design and develop PIGSAFE - an ASF disease risk-assessment and surveillance web-based geographic information system. The system will improve ASF disease surveillance and response. It is intended to profile pig owners and their farms which is a basic preventive and control technique against ASF (Martínez-López et al., 2015; Bulawit et al., 2024). Moreover, it can produce a risk assessment on the farm based on the risk factor scores set in the system to determine the degree of the biosecurity risk for each pig farm and the spatial risk level. Data from this can be applied to visualize a risk map and zoning hotspot in assisting with decision-making. The web application can also record the incidence of ASF and map geolocation for hotspot determination. It helps visualize data in real time that veterinary authorities and policymakers can use to make decisions. It helps in resource allocation hence ensuring effective deployment of the response team, quarantine zones, and focused surveillance efforts (Mathenge et al., 2022). In addition, the GIS will enable stakeholders to analyze control measures' effectiveness and be positioned to revamp strategies to enhance interventions that effectively counter ASF. Rapid Application Development technology was applied. This is an application development life cycle that is very fundamentally applied for web-based applications (Kurniawan and Rahmawati, 2024; Saputra and Kautsar, 2024; Sasmito et al., 2020). The system also utilized MapBox API for the mapping tool integrated into the web application with MySQL as its database management system.

Methodology

This research study focused on the design and development of a web-based application titled PIGSAFE: Pig Industry Geographic Surveillance and Assessment for Fever Emergencies for African Swine Fever. This study employed the developmental research approach using the Rapid Application Development model as the Software Development Life Cycle (SDLC). The RAD methodology was adopted since it allows for dynamic reviews and changes in system requirements as needed during system development including web applications (Sasmito et al., 2020; Widiyatmoko et al., 2024).

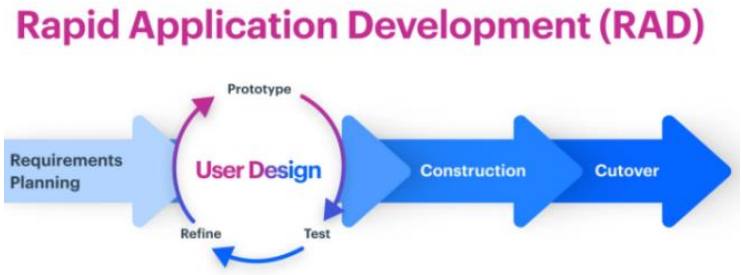

Figure 1. The RAD model.

Requirements Planning

In this phase, preliminary interviews by the researchers with personnel from the Municipal Agriculture Office (MAO) of the Municipality of Echague, Isabela. An inquiry was done to understand the current situation of the municipality about ASF management. Subsequently, the proponents conducted meetings and consultations with key stakeholders such as veterinarians, pig farm owners, MAO staff, and barangay officials to define system requirements and ensure the developed system addresses their specific needs. Additionally, the researchers also visit the Provincial Veterinary Office to get inputs for the possible risk factors and get important information such as recorded cases of ASF in the province and other information in line with the continuous spread of African Swine Fever. The system's functional and non-functional requirements

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were identified, including the network architecture, and identification of the hardware and software requirements were done.

demographic profile of the owner and farm information. This includes the GPS location of the farm which is used for mapping the farm.

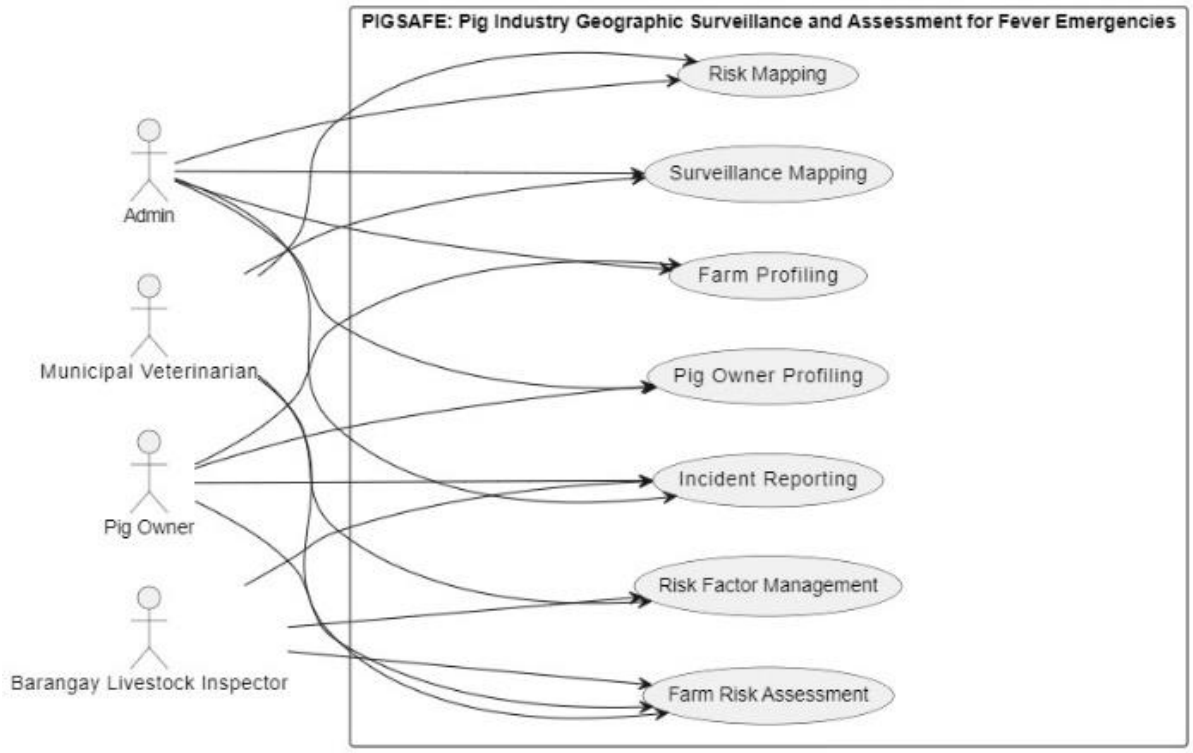

Figure 2. Use case diagram of PIGSAFE system.

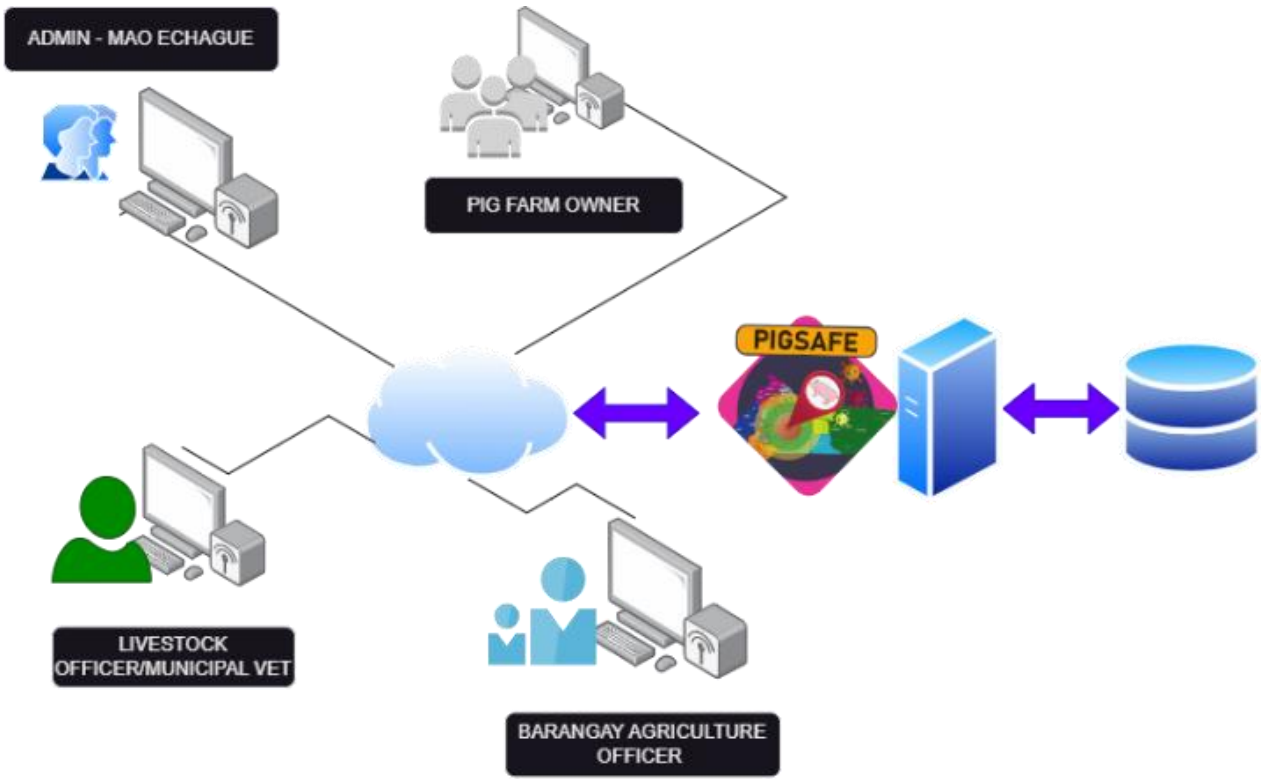

Figure 3. The system architecture of the Web-based application for ASF named PIGSAFE (Pig Industry Geographical Surveillance and Assessment for Fever Emergencies).

Functional requirements include pig owner profiling, farm profiling, farm risk assessment, risk factor mapping, disease incident reporting, and surveillance mapping as depicted in Figure 2. Pig owner profiling and farm profiling were done using a questionnaire to get the

User Design

Prototypes were created for the system's different functional requirements. The prototype for the dashboard was developed with different menus that show the system's different functional requirements. Along with it

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were the prototypes for farmer profiling, risk factor management, farm risk assessment, incident recording and reporting, incident mapping, biosecurity risk mapping, spatial risk mapping, and overall risk mapping. This was presented to the Provincial Veterinary Office and the Municipal Agriculture Office for their input and recommendations. Refinement and testing were done accordingly and presented again for approval. The cycle continued until all prototypes for each functional requirement were met satisfactorily.

System Architecture Design

Figure 3 shows the different stakeholders' connections to the online web GIS ASF mapping tool. The administrative part of the system will be managed by authorized personnel in the Municipal Agriculture Office of LGU Echague, Isabela.

Data Collection and Processing

the Biosecurity Risk Factor Weighted Risk Score, the Spatial Risk Factor Weighted Risk Score, and the Total Weighted Risk Score. These scores were then utilized as essential inputs for conducting farm risk assessments for each farm profiled in selected barangays of the municipality of Echague, Isabela.

The prototype developed for the system was tested and refined as needed. Different stakeholders were consulted about the prototypes and testing of the system's different modules.

Construction

The researcher used PHP as the scripting language for programming the system. Using JQuery, HTML5, and CSS, the system was designed and developed. MySQL was used as the backend database for storage of all the data that were used in the system. Mapbox, which is an established provider of personalized web maps for

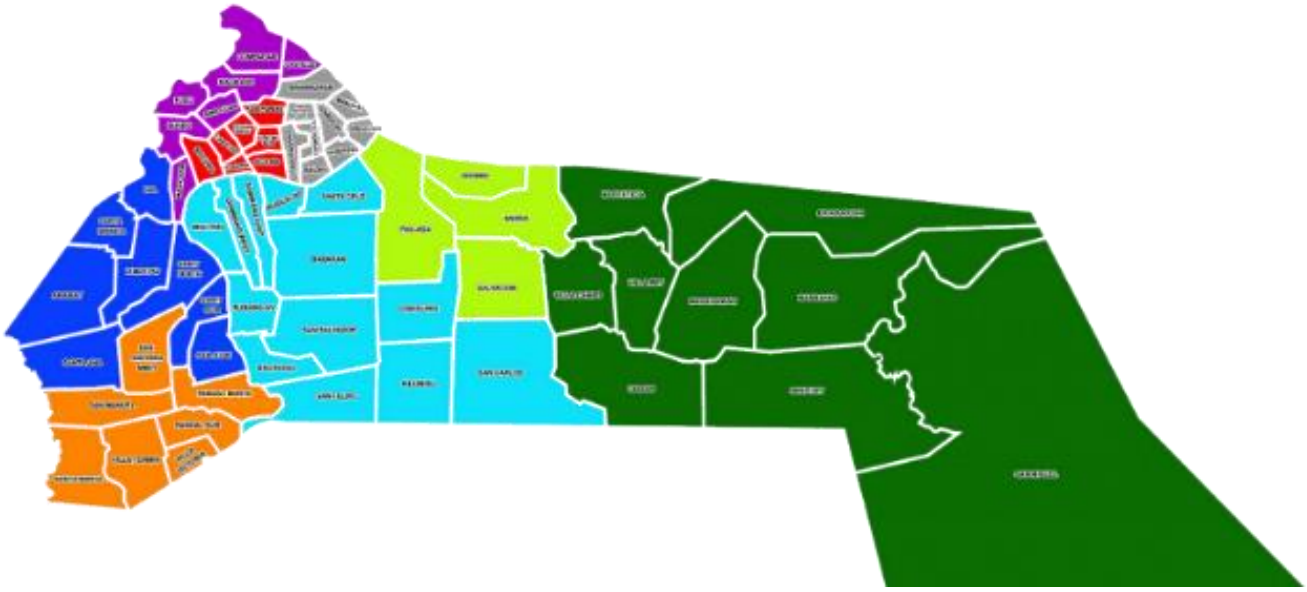

Figure 4. The location of the study is Echague, Isabela

The data used to implement the system is from the top 4 regions in the municipality of Echague, Isabela with high ASF cases in the past 5 years. This includes Ugad, Poblacion, Highway 3, and Highway 1 region of Echague, Isabela. For each region, the most affected barangay was chosen as the participating barangay. The Municipal Agriculture Office provided a list of affected farms per barangay to identify prospective farms**.** The demographic profile of the pig farm owners including the farm profile with geolocation as input for mapping and to have a complete understanding of the situation of each farm. All pig farm data was used as input for the system.

Different risk factors identified from the locale of the study were categorized into two primary groups: biosecurity and spatial risk factors. The computed risk scores were entered into the system based on their respective categories, resulting in three distinct scores:

websites and other applications, is used by the researcher. It provides a thorough framework that enables developers to produce stunning, engaging, and diverse data-rich maps for different purposes. Custom data were collected and encoded into the system, including the farm's GPS location, profile, and risk status. This made it possible to create maps that show certain data points related to farms' geolocation, risk level, and ASF incidence.

Cutover

The developed system was presented to the MAO of LGU Echague, Isabela for their comments**,** feedback, and recommendations. The inputs from the MAO personnel, especially those in charge of livestock, were considered in the continuous improvement of the system. Subsequently, the system was also presented to the Provincial Veterinary Office for comments and additional

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input. After considering all inputs and recommendations, the system was finalized and presented again. Training

Screenshot of the system

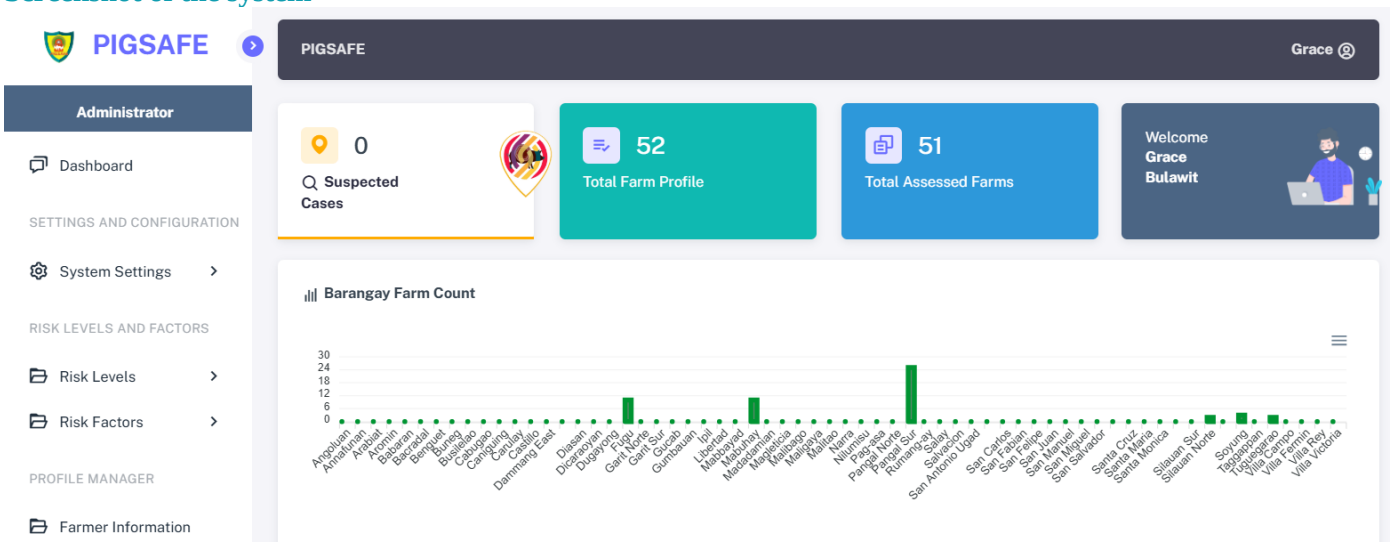

Figure 5. The PIGSAFE dashboard shows the different menus and graphs of the system.

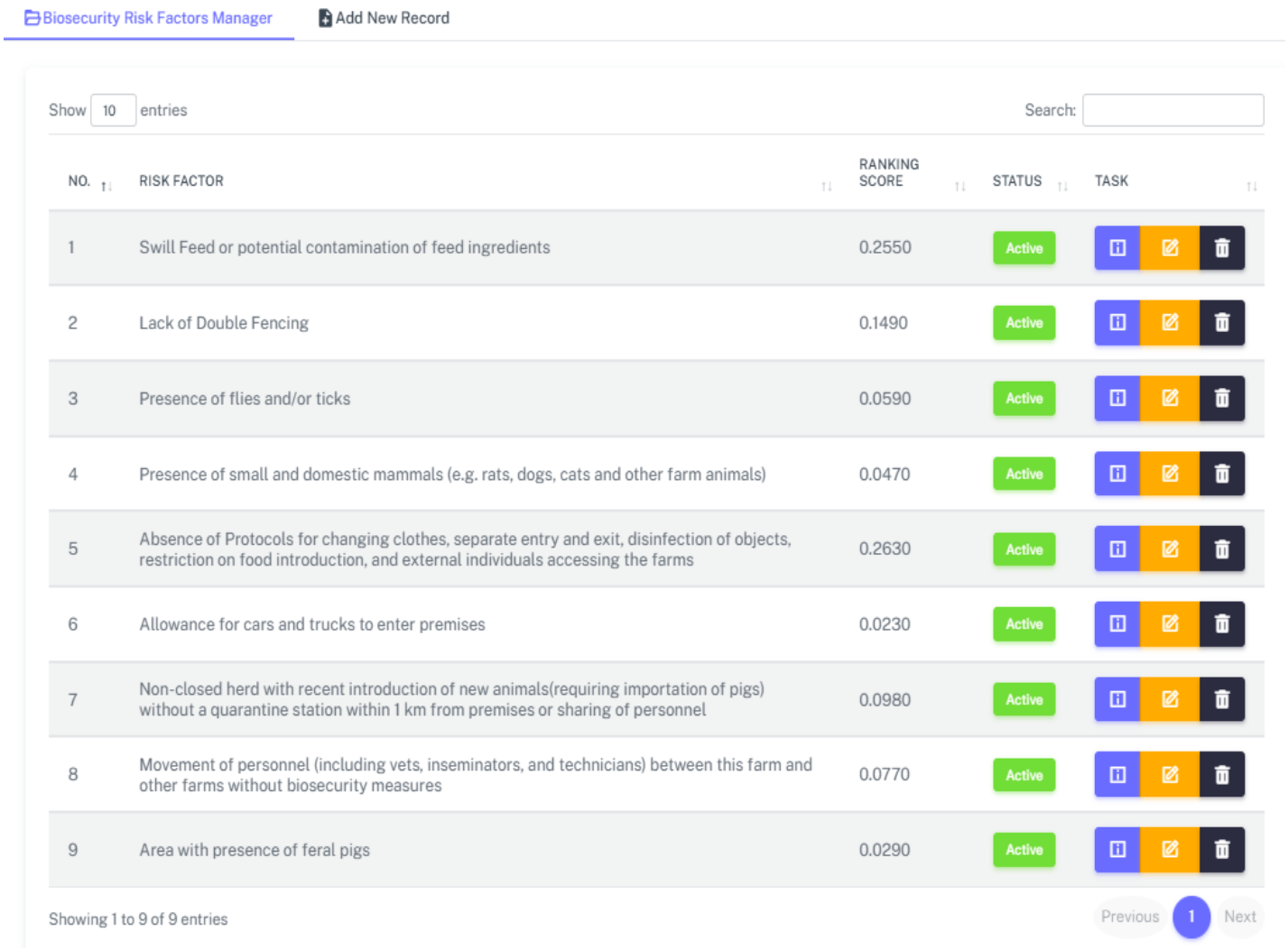

Figure 6. The Biosecurity Risk Factor Manager module allows the administrator to manage specific spatial risk factors.

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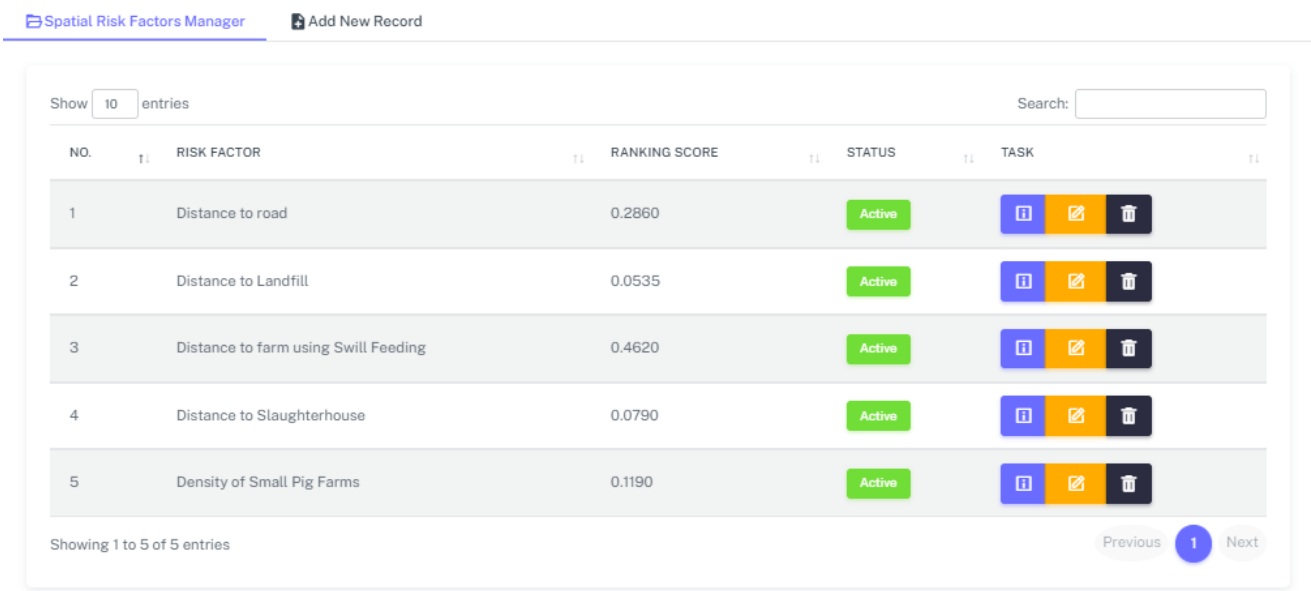

Figure 7. The Spatial Risk Factor Manager module allows the administrator to manage specific spatial risk factors.

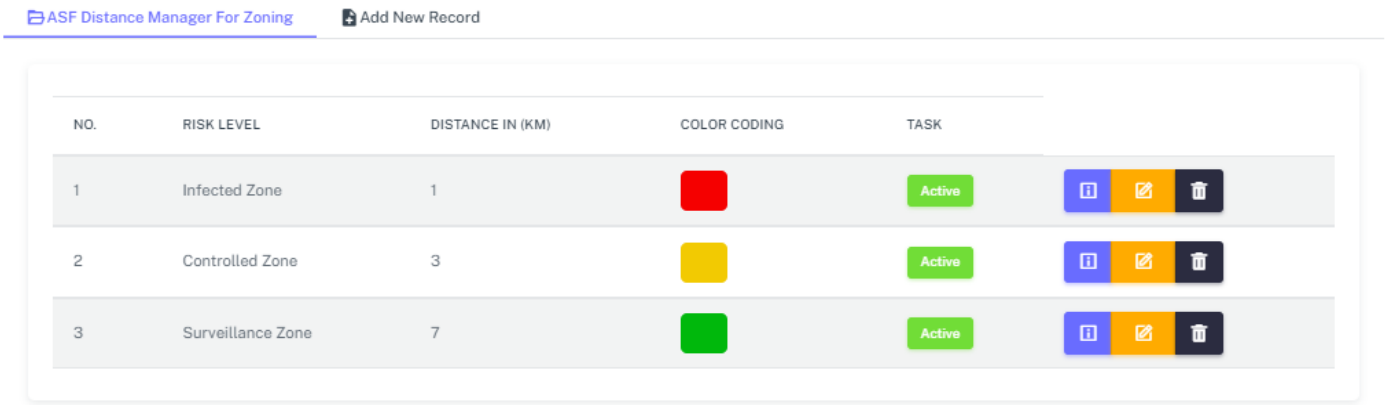

Figure 8. The ASF Distance Manager, where distances were managed to determine zoning.

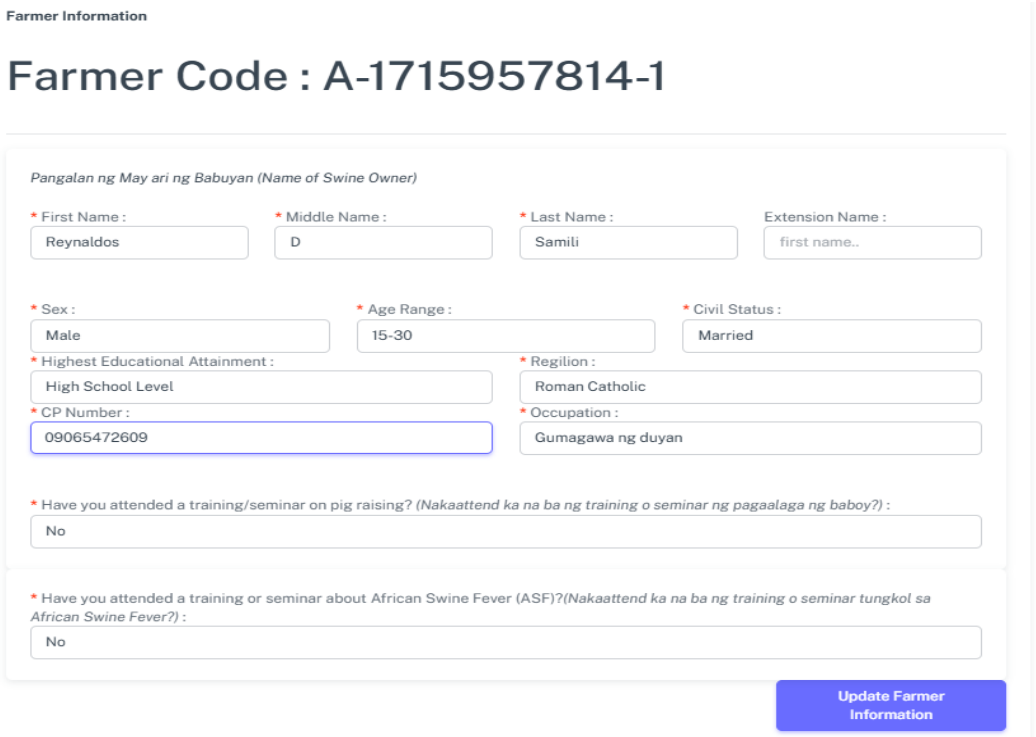

Figure 9. The Farmer Profile module, where the profile of the pig farm owner was encoded.

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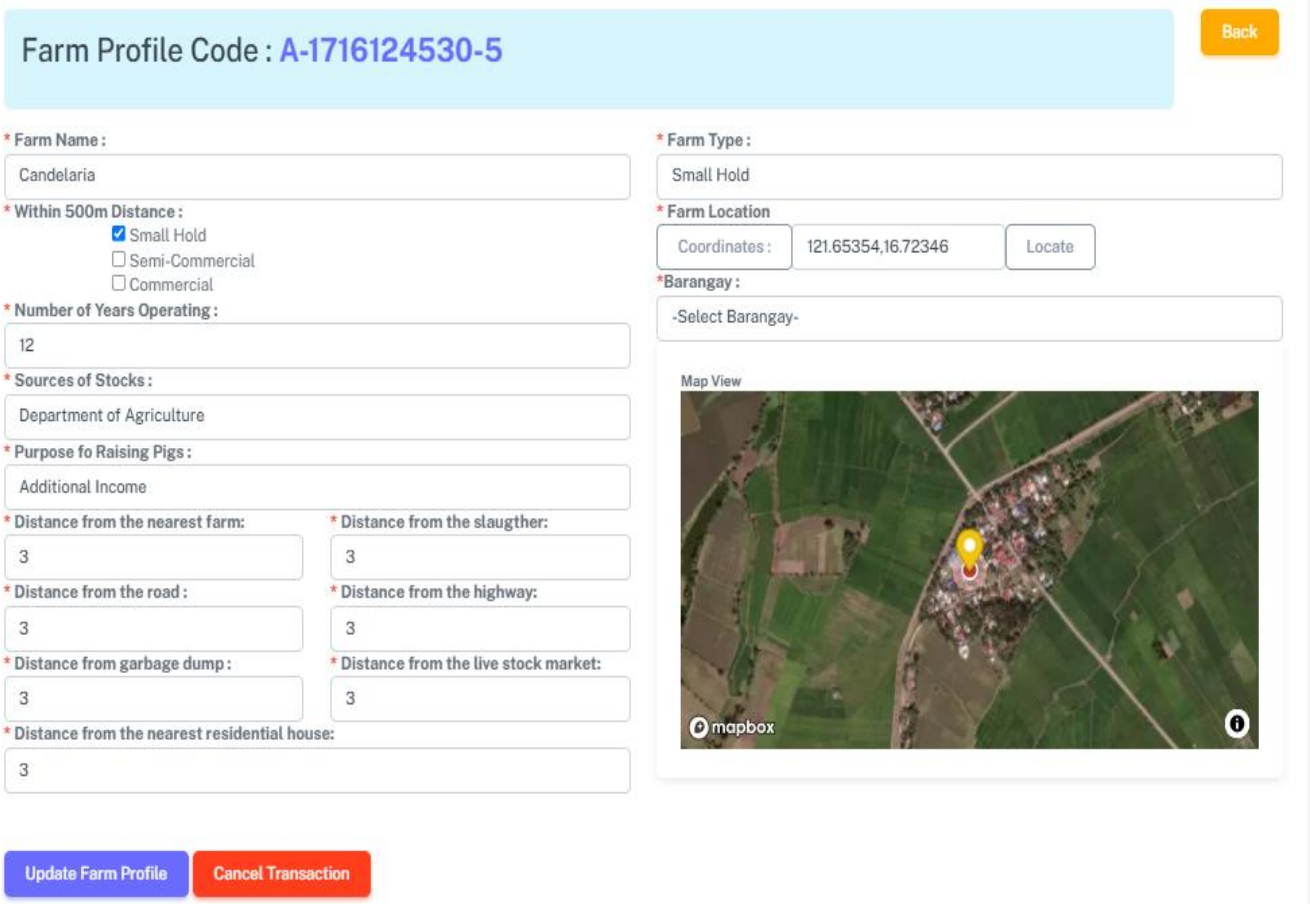

Figure 10. The Farm Profile module where a specific profile for each farm is managed by the administrator.

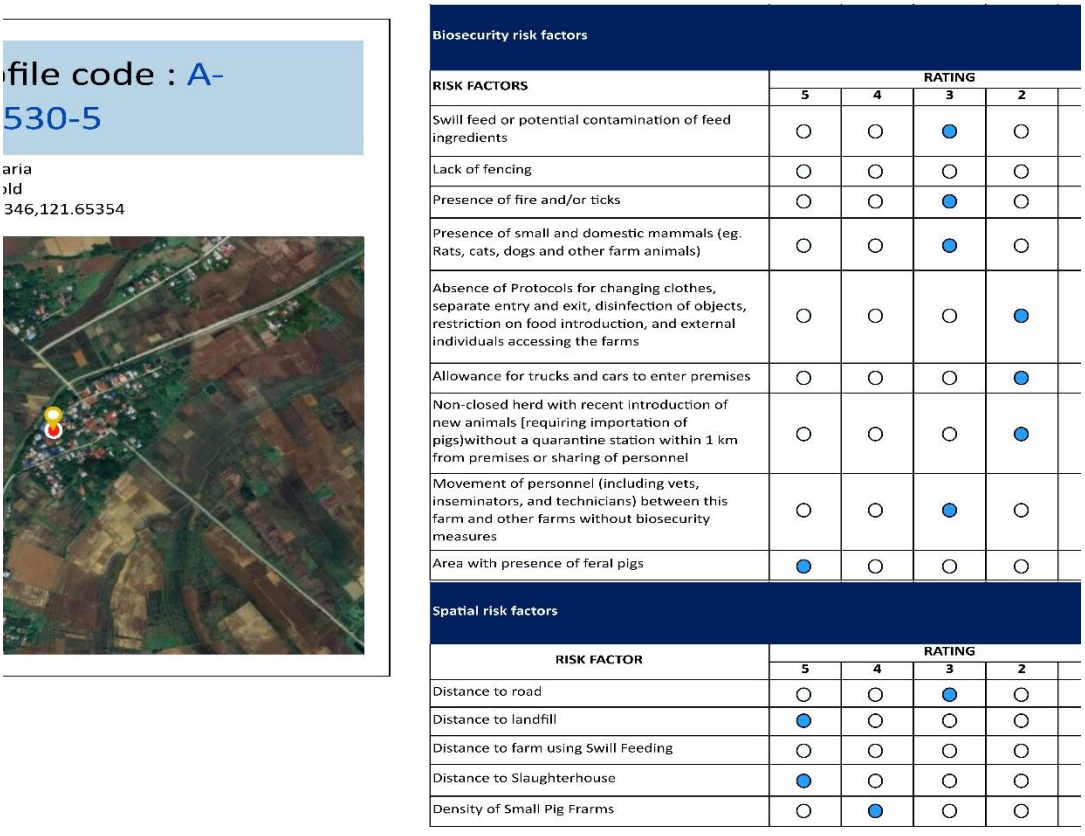

Figure 11. The Farm Biosecurity and Spatial Risk Assessment module, where each farm is assessed based on the different biosecurity and spatial risk factors.

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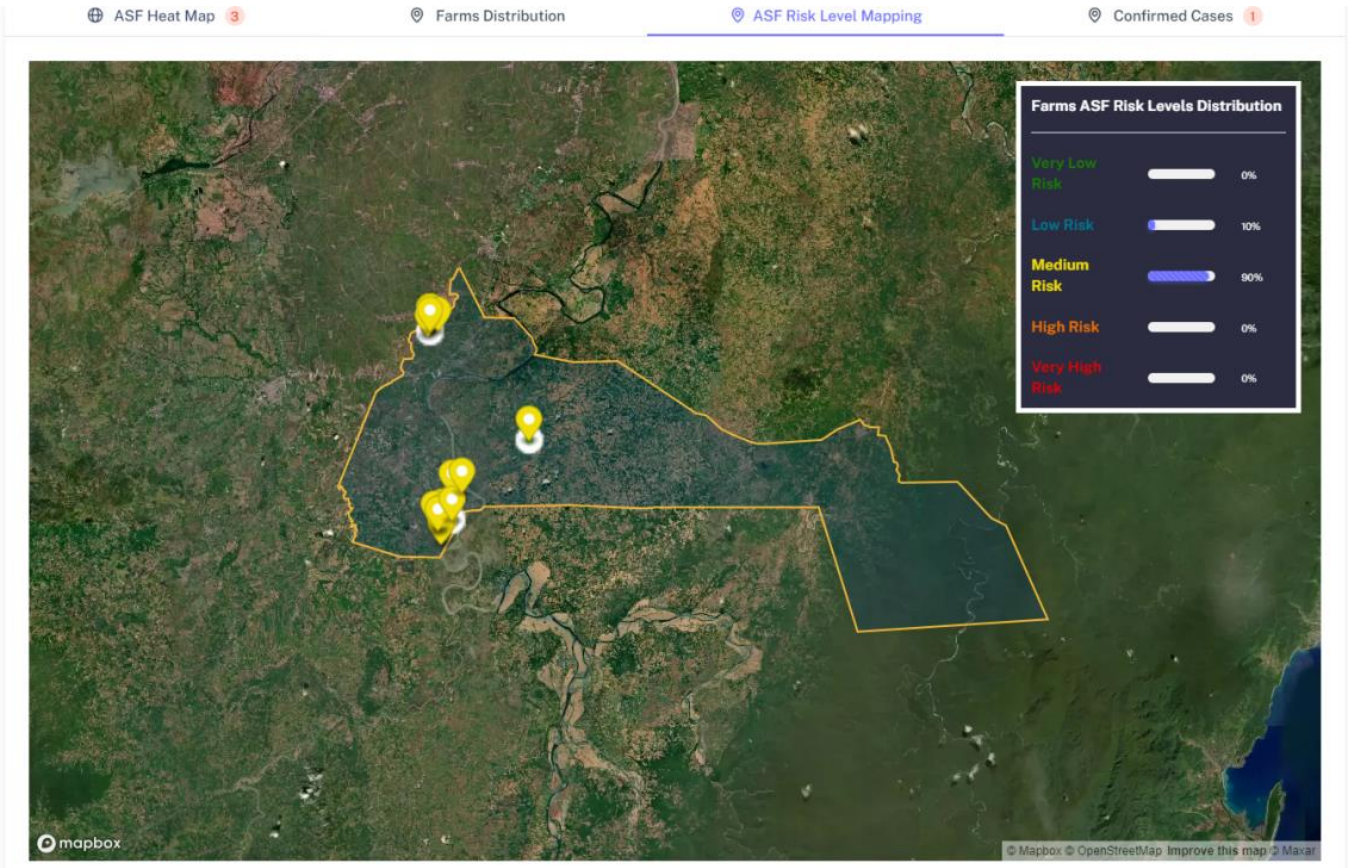

Figure 12. The ASF Risk Level Mapping module of the system, where farm distribution is shown including their risk level.

FARM ASSESSMENT REPORT | Fugu

Profile List | PDF Report

Export Excel Data

FARM INFO	ADDRESS	BIOSECURITY RISK		SPATIAL RISK		FARM'S ASF RISK
		TOTAL WEIGHTED RISK	RISK LEVEL	TOTAL WEIGHTED RISK	RISK LEVEL	
FP-1734057210-51 - Mabbayad **Farm Type :** Backyard **Owner :** Claro Acosta Mabbayad	Tuguegarao, Echague 121.69518, 16.70066	3.6890	High Risk	3.4665	High Risk	**High Risk** 3.57775000
FP-1716195482-10 - Millan **Farm Type :** Small Hold **Owner :** Allan B. Millan	Fugu, Echague 16.72197, 121.65402	2.6460	Medium Risk	4.0755	High Risk	**Medium Risk** 3.36075000
FP-1716213287-15 - Nagum **Farm Type :** Small Hold **Owner :** Merlita S. Nagum	Pangal Sur, Echague 16.595745, 121.663800	2.3400	Low Risk	4.2675	Very High Risk	**Medium Risk** 3.30375000
FP-1716215862-19 - Secolles, Johny **Farm Type :** Small Hold **Owner :** Johny C. Secolles	Pangal Sur, Echague 16.593631, 121.663883	2.3260	Low Risk	4.2675	Very High Risk	**Medium Risk** 3.29675000
FP-1716214428-17 - Daguro **Farm Type :** Small Hold **Owner :** Myriam S. Daguro	Pangal Sur, Echague 16.618542, 121.670191	2.4420	Low Risk	4.1015	High Risk	**Medium Risk** 3.27175000

Figure 13. The Overall Farm Risk Assessment Report where farm risk status is displayed and can be printed.

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was done on how the system is used with the staff of the MAO and pilot barangay officials.

Results

The developed system – PIGSAFE, has been uploaded online, tested, and implemented in the Local Government Unit of Echague, Isabela, specifically in the Municipal Agriculture Office, which oversees livestock management, including the occurrence of African Swine Fever disease. It can be accessed by authorized users for the administrator part of the web application. Other users, such as pig owners, livestock field officers, municipal veterinarians, and barangay officials, can use mobile devices and access the system through web browsers.

Discussion

The research study centered on the design and development of PIGSAFE: Pig Industry Geographic Surveillance and Assessment for Fever Emergencies for African Swine Fever represents a significant advancement in the management of ASF through technological innovation. Utilizing a developmental research approach aligned with the Rapid Application Development (RAD) model, the project emphasizes adaptability and stakeholder engagement throughout the system's lifecycle (Sasmito et al., 2020; Widiyatmoko et al., 2024). Preliminary studies and interviews were done with the Municipal Agriculture Office in Echague, Isabela, to determine the procedures the municipality was following for managing ASF and the needs of its stakeholders. Based on these findings, the functional and non-functional requirements were determined, including the appropriate hardware and software for the system. The iterative RAD process with continuous prototype improvement was possible in response to feedback from the stakeholders (Ardhana et al., 2022) .

The web-based architecture of PIGSAFE has multiple stakeholders and allows efficient data sharing and collaboration between the users. It is significant in the fight against ASF because an interdisciplinary, multi-sectoral strategy with effective, participatory resource allocation and management is essential (Plavsik et al., 2019). PHP, MySQL, and MapBox have been used at the back end to develop architecture dealing with complex data, such as pig farm profiling, risk assessments, and disease incident reporting. With GPS technology from MapBox, geographic mapping of risk, pig farm distribution, and suspected cases are developed. This provides key insights into the occurrence and spread of ASF disease (Blanton et al., 2006; Dahmani et al., 2022; Zhu et al., 2009). The selected barangays in Echague, which registered the highest number of ASF cases for the past five years, became focal points of data gathering. This narrow focus ensured that the system was based on relevant data that would allow for accurate risk assessments. Coupled together with being able to categorize risk factors into biosecurity and spatial dimensions, the system offers a complete understanding of vulnerabilities within the identified pig farms. The system has provided an easy tool through which pig farms and their respective ASF risk levels can be recorded and monitored easily.

The PIGSAFE system was implemented at the MAO of the Local Government Unit of Echague, Isabela. This includes orientation of the system and training of MAO staff and officials of the different barangays of Echague. During the training, comments and recommendations were also gathered as input for continuous input by the system. This multi-stakeholder approach improves user acceptance and ensures that the system can easily be integrated into the current ASF management protocols. However, the developed web application needs to be tested for a longer period to check for further enhancements. Continuous implementation in all barangays is also vital for a complete profiling and assessment of pig farms in the municipality. Other risk factors may be added into the system that could be dominant in other barangays of Echague, Isabela. This is important since each barangay has a different situation that may present other risk factors (Juszkiewicz et al., 2023; New Research Reveals Spatial and Temporal Patterns of African Swine Fever Outbreaks in the Philippines | College of Veterinary Medicine, 2023; Plut et al., 2023). The study can be expanded further to cover a bigger territory such as a legislative district or the whole province of Isabela. This will help in controlling the spread of ASF across the municipalities and the whole province.

Conclusion

The developed web-based PIGSAFE application is a tool beneficial for the fight against African Swine Fever in the Municipality of Echague, Isabela, Philippines. It addresses the critical need for efficient surveillance and assessment tools affected by ASF, particularly in the Municipality of Echague, Isabela. Rapid Application Development offers a promising approach for developing a web-based animal disease surveillance and mapping system. Its speed, flexibility, and involvement of users correspond well to the dynamic nature of outbreaks of animal diseases. Using MapBox has also brought an innovative feature because it integrates maps and provides surveillance of animal diseases through its

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innovative mapping applications. The study supports the importance of stakeholders in this process and gives this development importance to its iterative design processes and technological integration supports an effective animal health surveillance system(Dahmani et al., 2022b). The developed web app has effectively performed farm profiling, risk assessment, risk mapping, and surveillance mapping which offers a promising enhancement to the current approach toward ASF. It improved the capabilities of enhanced surveillance and response strategies for Echague, Isabela, against ASF outbreaks. The inclusion of biosecurity and spatial risk factor mapping also helps in the full understanding of the ASF situation of the municipality. This would be the basis of strategic interventions and policy reinforcement by the Local Government of Echague, Isabela, in ASF management. In addition, the developed web application avoids long and time-consuming disease mapping which requires supplementary software for processing and analysis of data possibly costing costly licensing. It also enables the LGU to develop web applications tailored to those needs that may particularly be applicable in addressing the ASF problem in the municipality based on the risk factors prevailing.

Conflict of interest

None

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